

**EFFECTS OF PRIMING VISUAL RELATEDNESS AND
EXPECTANCY ON VISUAL SEARCH PERFORMANCE**

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EFFECTS OF PRIMING VISUAL RELATEDNESS AND EXPECTANCY ON VISUAL SEARCH PERFORMANCE

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LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	analysis of variance
ISI	inter-stimulus interval
ITI	inter-trial interval
ms	milliseconds
RT	response time

SUMMARY

The current study examined two means of reducing uncertainty in visual search: 1) visual relatedness of a prime to the target (a data-driven, bottom-up processing) and 2) expectancy (a top-down process based on the proportion of validly primed trials). The two processes were decoupled using a short and a long inter-stimulus interval (ISI) to examine their time course in visual search. Competing hypotheses were contrasted in order to determine whether relatedness is associated with iconic memory (Neely, 1977) or a longer lasting visual-structural implicit memory (Schacter & Cooper, 1995) and what role participant expectancy plays in visual search performance.

Twelve participants engaged in a discrimination task and a visual search task. The obtained results suggest that visual relatedness is a bottom-up process, probably mediated by a short-term iconic store that affects search performance early, but whose effects rapidly decay. They also suggest that expectancy is a top-down process that requires time to build up before it can affect visual search performance, but whose effects are more long lasting than visual relatedness.

CHAPTER 1

INTRODUCTION

Identifying and locating a target amid distracting information increases in difficulty as a function of the ambiguity regarding the target. Not knowing where or what the target will be increases uncertainty and results in a more error prone, protracted search. Several methods have been used to reduce uncertainty, thereby maximizing the efficiency of target recognition. One such paradigm that has been repeatedly employed in psychological research to accomplish this is the priming paradigm.

Typically priming paradigms involve the presentation of a stimulus (the prime) followed by a second stimulus (the target) with some delay between the offset of one stimulus and the onset of the next, the inter-stimulus interval (ISI). Participants are required to make some type of judgment about the target stimulus and either the accuracy or response time (RT) of this response is measured. The basic empirical question examined in these paradigms is what effect, if any, does the presence of the prime have on judgments made about a target?

Previous priming research has emphasized semantic priming and matching or classification tasks (e.g., Graf & Schacter, 1985; Neely, 1977; Posner & Snyder, 1975; Schacter, Cooper, and Delaney, 1990) in a cognitive domain. Moreover, some research suggests that structural (visual) representations are maintained separately from semantic information (Riddech & Humphreys, 1987). The current study extends the underlying concepts from a cognitive domain (e.g., semantic priming) to a perceptual-cognitive domain (e.g., visual priming) and examines how visual relatedness of prime-target

pairings and participant expectancy each influence the everyday perceptual phenomena of visual search.

PRIMING EFFECTS

Priming effects are typically manifested as a change in the speed or accuracy of judgments about a target stimulus resulting from prior exposure to another stimulus, the prime. Priming effects can manifest either as benefits (e.g., increased accuracy) or costs (e.g., decreased accuracy). These changes presumably occur without any intention and even in the absence of memory for the prime (Meyer & Schvaneveldt, 1971), suggesting that these changes are both involuntary and unconscious.

Posner and Snyder (1975) used a priming paradigm to examine the effects of prime-target relatedness and participant expectancy on target identification in a matching task. In this study participants were presented first with a prime (a single letter) followed by a visual array of two letters. The participant's task was to determine if the letters in the subsequent target display were both the same as the prime (i.e., related) or different. Posner and Snyder varied the proportion of trials in which the prime accurately predicted the target, thereby varying participant expectancy. They also manipulated the ISIs (varying from 10 to 500ms) to determine if the effects of the prime would result in different benefits and costs at shorter and longer ISIs.

Their results indicated that at shorter ISIs, when prime-target pairs were identical, response time (RT) was reduced in comparison to different prime-target pairs and a neutral condition, regardless of the participant's expectations. They also demonstrated that this effect decreased at longer ISIs, where expectancy effects based on the predictive probabilities of prime-target pairs were assumed to influence the degree of benefit. At

longer ISIs RT was faster on trials where the probability was high for a particular target/prime pairing and that target did in fact follow the prime (in comparison to unexpected and neutral conditions), regardless of whether the expected prime-target pair was the same or different. These results suggest that there are two different processes involved in semantic priming and matching tasks, relatedness and expectancy, and that they each affect performance through different time courses. They suggested that relatedness is fast acting but short lasting whereas; expectancy is slow acting but persists longer (Posner & Snyder, 1975).

Neely (1977) used a priming paradigm to examine the effects of categorical priming on a lexical decision-making task. In this study, three fundamental manipulations were utilized to examine prime-target relatedness and expectancy. First, the degree of prime-target relatedness was manipulated by having both related and unrelated prime-target pairs. For example, in a related pair the prime may have been the word *bird* and the target *robin* (Related-Expected in Figure 1). An unrelated pair may have been a condition in which the prime was the word *bird* and the target *arm* (Unexpected-Unrelated condition in Figure 1).

Second, Neely manipulated prime validity (i.e., the proportion of trials in which the prime accurately predicted the subsequent target) to examine the effects of expectancy. For example, in an expected condition participants were told that if the prime was the word *bird* then the target would be a type of bird 80% of the time. Hence when participants saw the word *bird* they expected the target to be a type of bird (e.g., *bird-robin*). If the participant saw the word *bird* and the target was *arm* the target was both semantically unrelated and unexpected.

Finally, ISI was manipulated to determine whether the effects of relatedness and expectancy varied over time. This was done to test the hypothesis that relatedness affected RT at short ISIs whereas expectancy requires time to build up before its effect on performance can be seen. Neely measured performance by recording RT and defined benefits as the degree to which RT was decreased and costs as the degree RT was increased compared to a neutral condition. Figure 1 illustrates the results obtained in this study. The x-axis represents the varying ISIs and the y-axis represents the degree of benefits (*facilitation*) and costs (*inhibition*).

The results of this study provide converging support for those of Posner and Snyder (1975). That is, related prime-target pairs resulted in better performance at short ISIs regardless of expectancy and at longer ISIs this effect dissipated and better performance was associated with expected prime-target pairs regardless of relatedness.

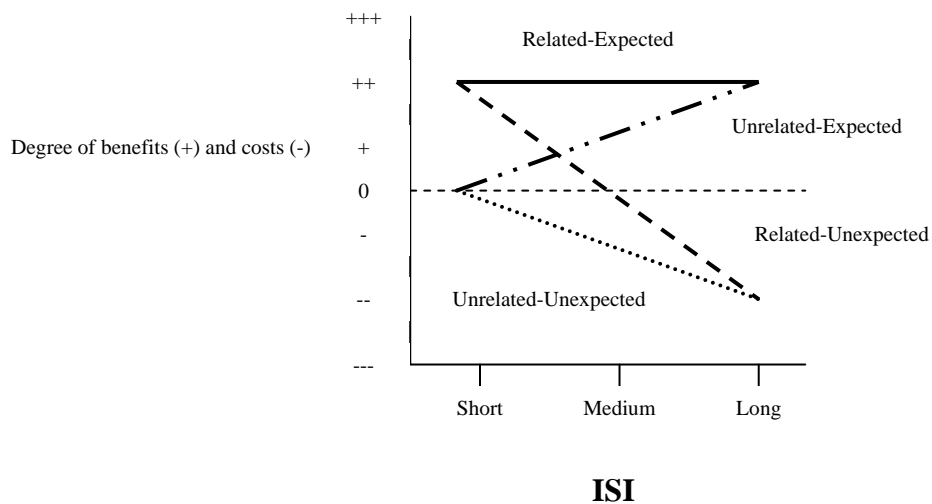


Figure 1 – Degree of benefits and costs as a function of ISI adapted from Neely (1977).

Both of these studies suggest there are two distinct processes that follow different time courses. The first is prime-target relatedness. This process is automatic and

immediately available to the system for processing, but is assumed to decay quickly. The second is participant expectancy, which requires time to develop before it is available to the system for processing and persists much longer (Posner & Snyder, 1975; Neely, 1977).

VISUAL SEARCH

Visual search typically involves identifying and locating a target stimulus that is embedded within an array of distracting information. People perform visual search tasks frequently each day. These tasks vary in difficulty ranging from relatively easy and effortless searches, such as visually locating a telephone on a cluttered desk, to far more complex searches, such as visually identifying a previously unknown person in a crowded restaurant based only on a brief, vague description.

Two types of processing identified as being involved in visual search are bottom-up processing (e.g., Treisman & Gelade, 1980; Palmer et al., 1993) and top-down processing (e.g., Treisman & Gelade, 1980; Wolfe, 1994). The current study addressed both of these by manipulating visual relatedness (a bottom-up process) and participant expectancy (a top-down process) to examine how each influence visual search performance.

BOTTOM-UP PROCESSING AND VISUAL SEARCH

In bottom-up processing, information from the physical stimulus enters through the sensory receptors and is fed forward to the brain. This is strictly a data-driven process in that the physical properties of the stimulus determine the patterns of activity generated and the resulting percepts. This “raw” or unprocessed visual information

remains available to the system for a very brief period of time before it decays (cf. Neisser's (1967) or Sperling's (1960) iconic store).

Several modern theories stress the importance of bottom-up processing in visual search. Feature integration theory (Treisman & Gelade, 1980; Treisman, 1988) suggests that there are two phases in the visual search process. The first phase is driven exclusively by bottom-up processing. During this phase all of the visual stimuli present in an array are processed pre-attentively and in parallel at the level of the individual physical properties, or features. Bottom up processing also plays a major role in Wolfe's (1994) Guided Search approach. Like feature integration theory, the guided search approach also includes a pre-attentive phase in which the physical features of all stimuli are compared in parallel to those of their neighbors. Examples of these features include color, orientation, and luminance. Special feature detectors then group the individual feature vectors into feature maps (see Enns & Rensink, 1991, for an alternative view of pre-attentive processing).

TOP-DOWN PROCESSING AND VISUAL SEARCH

In top-down processing it is assumed that higher cognitive processes work in addition to the bottom-up properties of a stimulus to shape human perception. Several approaches of visual search have addressed the role of top-down processing. In Wolfe's Guided Search model (1994) a participant's knowledge of the task requirements can influence the relative contributions of the several different feature maps to the activation map. This model states that it is top-down influences that dictate which features will be looked for when discriminating and detecting a target stimulus. Wolfe claims that these top-down influences act on feature maps and give greater weight to features that have less

interference from distractor stimuli. In the present study the Guided Search model would predict that if the participant is told ahead of time that a specific target will be present (i.e., expects a certain target) the activation associated with the geometric components of that target will be weighted more heavily as they have less interference from the distractor stimuli.

VISUAL RELATEDNESS OF PRIME AND TARGET

In a series of studies (e.g., Schacter and Cooper, 1993; Schacter, Cooper, & Delaney, 1990; and Schacter, Cooper, Delaney, Peterson, & Tharan, 1991) investigating the ability to discriminate between possible and impossible objects, Schacter, Cooper, and their colleagues presented participants with study lists of three dimensional line drawings. After studying these lists participants were then presented with more briefly displayed line drawings some of which had been previously studied and the rest were novel stimuli. The participant's task was to identify these brief displays as being either structurally possible or impossible. In these studies priming effects were said to exist when a drawing from the studied list altered the likelihood of the participant responding either possible or impossible as compared to previously unstudied objects.

The overall interpretation Schacter and Cooper offer from these studies and the multiple manipulations used is that priming effects are dependent on a *visual-structural description* of the object (Schacter & Cooper, 1995). Furthermore, they contend that this structural description is stored implicitly in memory. To support this claim they cite their own research involving anterograde amnesiacs (Schacter et al., 1991) in which priming effects (as defined above) occurred in the same fashion.

The work of Schacter and Cooper seems to suggest that the benefits and costs associated with priming visual-structural information is immediately apparent for processing, a position that agrees with the earlier cognitive psychology research (e.g., Neely, 1977; Posner & Snyder, 1975). Where Schacter and Cooper differ from this earlier research is with regard to the persistence of information about visual relatedness. They argue that this information does not decay rapidly but is stored implicitly in memory where it persists much longer (Schacter & Cooper, 1995). In order to distinguish between these two competing ideas the present study used visual stimuli to prime visual relatedness and examine its effects on visual search performance.

The visual stimuli used in the current study were designed based on the work of Newell, Brown, and Findlay (2004) examining the mechanisms of object-based search. In their exemplar condition Newell et al. (2004) developed stimuli by combining simple geometric components. Each of the stimuli shared the same structural arrangement of components but target and distractor stimuli varied on some metric of those components for example, a cone instead of a truncated pyramid for the triangular portion as shown in Figure 2.

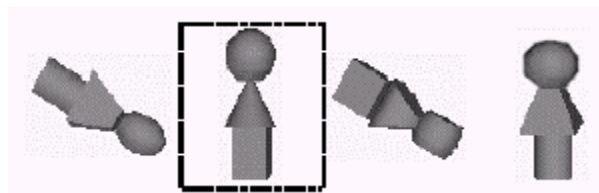


Figure 2 – Example of exemplar based stimuli from Newell et al. (2004). The item with the border is the target stimulus and the other three are distractor stimuli.

As in Posner and Snyder's (1975) priming study, relatedness in the current study was manipulated by using a combination of prime-target pairings that were either the

same or different. In the study reported here, relatedness was not defined by semantic similarity (e.g., Posner & Snyder, 1975; Neely, 1977) but rather by the degree to which prime-target pairings contained the same geometric components arranged in the same structural order (i.e., visual similarity). Same pairings contained the same components arranged in the same structural order while different pairs contained slightly modified components (e.g., an ellipse instead of a rectangle), but the components were arranged in the same structural order. Thus, in the current experiment all stimuli were structurally related to each other, but whereas some prime-target pairs were identical (*same*), other pairs were not (*different*), see Figure 3.

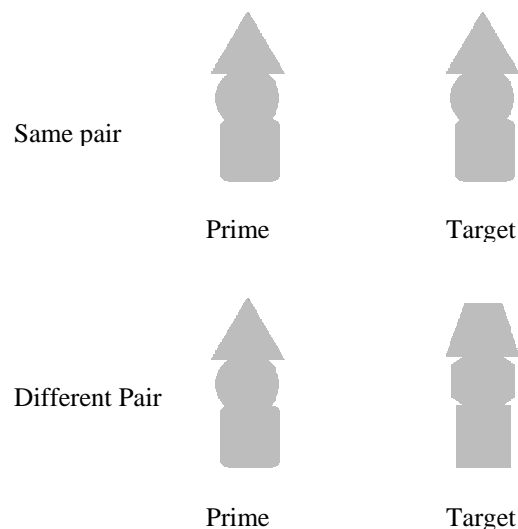


Figure 3 – Examples of pair types used in current study

PRIME-TARGET EXPECTANCY

Müller, Reimann, and Krummenacher, (2003) conducted several experiments examining the effect of expectancy based on priming specific dimensions of stimuli (e.g., frequency of appearance). In their experiment the ISI was not manipulated the inter-trial interval (ITI) was. For validly primed trials (i.e., related) they used a short ITI of 500ms

and on invalidly primed trials a longer ITI of 1000ms. Their results indicate that expectancy produces faster RTs (benefits) for validly primed trials and slower RT (costs) for invalid trials when compared to a neutral condition in visual search.

In this study participant expectancy was manipulated by using three different conditions, an 80% valid condition (in which on 80% of the trials the target was identical to the prime), a 20% valid condition, and a 50% valid condition. These conditions were used to decouple visual relatedness and expectancy. For example, if the prime is only valid on 20% of the trials, the observer expects the target to be *unrelated* to the prime, whereas, if the prime is valid on 80% of the trials, the observer will expect the target to be *related* to the prime. In the case where the prime is valid on only 50% of the trials, however, maximum uncertainty characterizes which of two targets will be presented thus, expectancy should not affect performance. In this way, the effects of expectancy and relatedness can be decoupled.

MANIPULATING ISI

Neisser (1967) coined the term iconic memory and identified it as a transitory (lasting no longer than 500 milliseconds) photographic like, pre-categorical visual representation that remained available for only a brief time after exposure to a visual stimulus. Coltheart (1980) later identified two major constituents of iconic memory, visible and informational persistence.

Coltheart's visible persistence refers to the short-lived visual representation described by Neisser, and informational persistence refers to a higher-level process that maintains some spatial and structural information. This informational persistence may be analogous to, but not nearly as long lasting as, the structural description that Schacter and

Cooper (1995) claim is responsible for the benefits associated with visual relatedness. Coltheart's informational persistence lasts for roughly 150 – 300 ms and then decays while Schacter and Cooper's structural descriptions persist much longer and can even span multiple testing sessions (Schacter and Cooper, 1995).

In the present study, ISI was manipulated in an attempt to distinguish between the two approaches and the assumptions they make in order to determine if the effect of relatedness is fast acting and decays rapidly (i.e., stored in iconic memory, Neely, 1977) or whether the effect persists as structural information in implicit memory (e.g., Schacter, et al., 1990). By manipulating ISI it was also possible to test the assumption that expectancy requires time to build before becoming available to the system.

OVERVIEW OF EXPERIMENT, ASSUMPTIONS, AND PREDICTIONS

The current study employed a visual search paradigm in order to examine the effects of priming visual relatedness and participant expectancy on visual search performance. Figure 3 shows predictions based on Neely's semantic priming paradigm (shown on the left) and based on Schacter and Cooper's visual structural implicit memory (shown on the right). To test these hypotheses three experimental groups (80%, 50%, and 20% valid primes) that differed on the expected proportions of same prime-target pairs were employed. The predictions are based on the assumptions described below:

Assumptions

1) Short ISI assumptions: At a short ISI same prime-target pairings should produce better performance levels than different pairs. That is, visual representational information will be available rapidly and automatically to the observer. Both Neely's and Schacter and Cooper's approaches predict that at a short ISI participant expectations will

not influence performance. Thus, at the short ISI, it should not matter whether the prime is valid or invalid, only the visual relationship between the prime and target should affect accuracy and response time. This is because expectancy requires time to build up before it is available to the observer.

2) Long ISI assumptions: Both Neely's and Schacter and Cooper's approaches predict that expectancy may affect results at a long ISI, if there has been sufficient time for it to build up. Moreover, Neely's paradigm suggests that visual information fades quickly, as the iconic store decays, so that at longer ISIs visual relatedness has no effect and only expectancy influences performance. In contrast, Schacter and Cooper's implicit memory research suggests that visual information may be retained within implicit memory for much longer durations, so that its effect would still be evident at longer ISIs and would interact with the effects of expectancy. Thus, at long ISI predictions based on Schacter and Cooper's approach are more complicated, including effects of both implicit memory and expectancy, than those based on Neely's, which only includes expectancy's effects.

3) Decoupling Expectancy and Visual Relatedness Assumption: When the prime provides no useful information about which target will be presented on a given trial, then expectancy plays no role. That is, if the prime is valid on 50% of the trials, then the participant does not know which of two targets will be presented. On such trials, only visual relatedness should affect performance. This is a crucial assumption that lets one isolate the effects of visual relatedness on search performance.

Predictions

- a. In the 80% valid condition expectancy and visual relatedness should operate compatibly. Neely would predict performance at the long ISI is similar to that at the

short ISI: performance on same prime-target pair trials should be much better than performance on different prime-target pair trials. At a long ISI Schacter and Cooper's approach would predict even better performance in the same pair trials and worse performance in the different pair trials than Neely would predict.

- b. In the 50% valid condition the prime provides no useful information about which of two targets will be presented and, thus, expectancy plays no role. According to Neely's predictions, there should be no difference in performance for same vs. different pair trials at the long ISI. In contrast, Schacter and Cooper's approach would predict performance at long ISI to be similar to that at the short ISI: performance on same target-prime pair trials should be better than on the different prime-target pair trials.
- c. In the 20% valid condition the prime predicted the occurrence of an identical target on only 20% of the trials, therefore the participant will expect an unrelated prime-target pair on 80% of the trials. Neely's approach predicts better performance at the short ISI for the same pairs and better performance at the long ISI for the expected, different pairs. In other words, Neely's approach predicts that performance at the long ISI will be the reverse of that at the short ISI (viz., a significant interaction effect).

At the long ISI, predictions for the Schacter and Cooper approach depend on the relative strength of expectancy versus visual implicit memory. If expectancy is much stronger than visual implicit memory, then the prediction is similar to Neely's, which assumes visual relatedness has no effect at long ISI. If expectancy's strength is similar to that of visual implicit memory, then they may cancel each other so that

there is no difference in performance between same- and different-pair trials at the long ISI. Finally, if expectancy is much weaker than visual implicit memory, then performance at the long ISI should be similar to that at the short ISI: performance on same pair trials should be much better than performance on different pair trials.

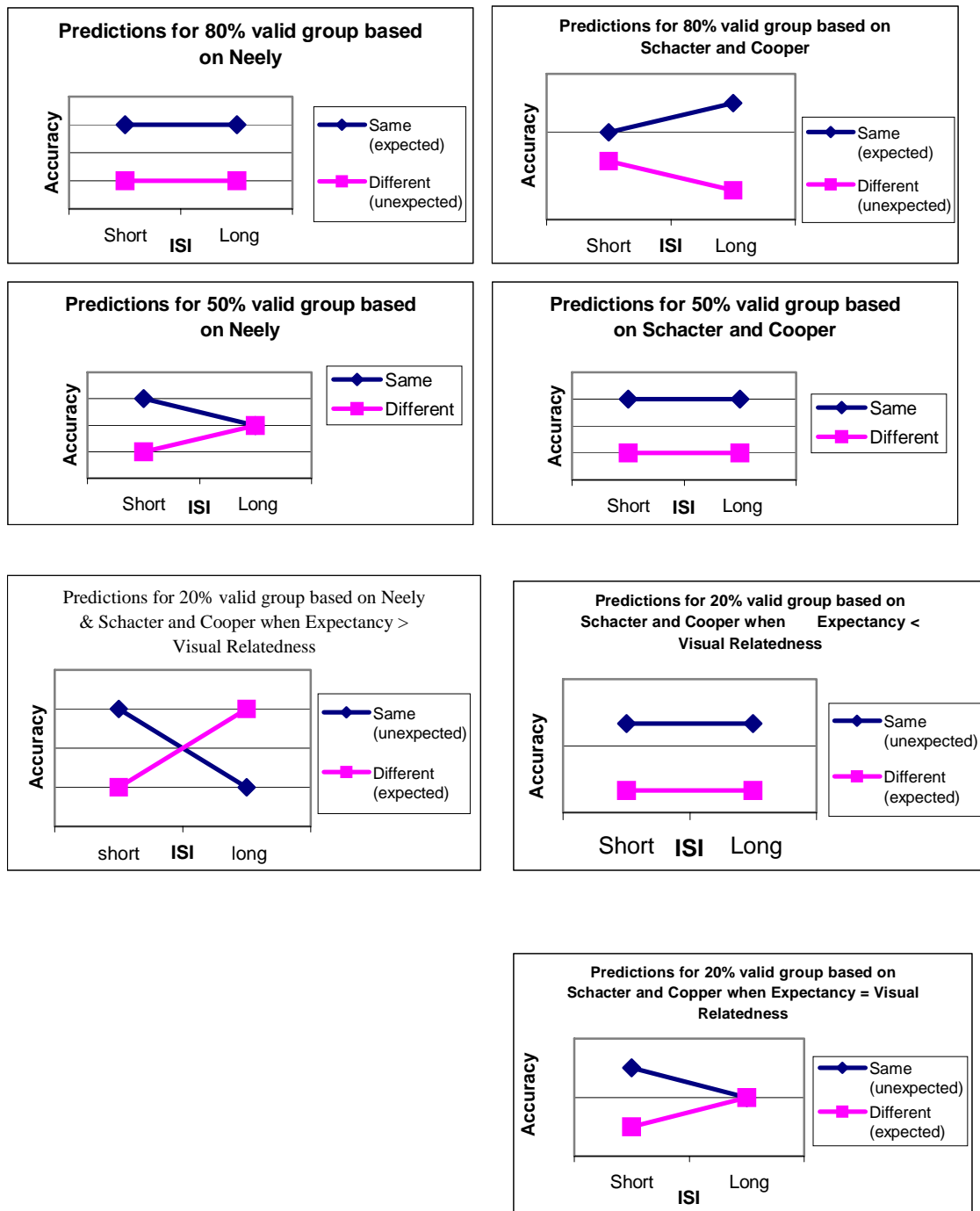


Figure 4 – Competing predictions from Neely (1977) and Schacter & Cooper (1995)

CHAPTER 2

THE EXPERIMENT

PARTICIPANTS

Seven male and five female university students (mean age of 21 years) volunteered for this study. All participants were screened to ensure normal near and distance visual acuity after any necessary refractive correction. All participants indicated informed consent by signing a consent form at the beginning of the experimental session.

APPARATUS

Tasks in this study were conducted on two Dell Dimension 8100 series computers with Sony Trinitron 19" viewable color monitors and standard "qwerty" keyboards. Computer programs written in Psychology Software Tools' E-prime version 1.1 (Schneider, 1988) were used to control stimulus presentation and to record participant responses.

STIMULUS CONSTRUCTION

The stimuli used in this study were created using Pixologic's graphic software, Zbrush 2.0. Stimuli were designed so that at a viewing distance of 28.5 inches each stimulus in a given array subtended a visual angle of 2.5°. The two target stimuli (A and B) differed in their geometric components (see Figure 5).

Two types of distractors were used in this study. Each distractor contained at least one geometric shape from each of the two target stimuli. Homogeneous distractors were used in each trial and the type of distractors varied from trial to trial. The target

stimuli were more similar to either of the distractors than to each other. The similarity between target and distractor helps minimize any potential pop-out effects. Moreover, randomly varying the distractors from trial to trial makes it impossible to distinguish target from distractor by focusing on only one component (e.g., always attending to the top component). Figure 5 shows examples of the two target stimuli and the two types of distractors. They are arranged spatially to illustrate their similarity to each other (i.e., to show that both targets are more similar to the distractors than to each other).

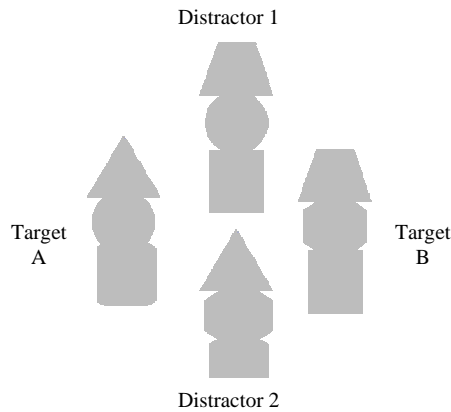


Figure 5 – Stimuli arranged spatially according to similarity: Target A is on the left, Distractor 1 is the top middle image and Distractor 2 is the bottom middle, Target B is the image on the far right.

A display size of four was used for all trials. Luminance, contrast, display size, and spatial arrangement of stimuli were held constant throughout the experiment to eliminate any potential confounding perceptual factors (Palmer, 1993). Each trial contained one target stimulus (either A or B) and three distractors. Stimuli in the search array were spatially arranged so that one item appeared in each quadrant of the search array as shown in Figure 6. The target appeared randomly in one of the four quadrants.

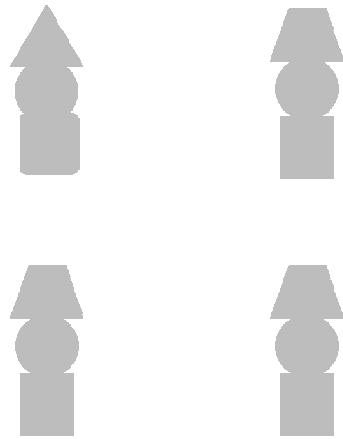


Figure 6 – Spatial Layout of Test Trials

EXPERIMENTAL DESIGN

The current study employed a 3X2X2 mixed measures design. The between subjects factors included both prime validity (20%, 50%, and 80%) and prime (A or B). Thus, one-third of the participants were tested with 80% valid primes, one-third with 50% valid primes, and one-third with 20% valid primes. Moreover, for half of the participants target A was used as the prime stimulus and target B for the rest of the participants.

Each participant was tested using trials involving both the short and long ISI. Thus, short ISI vs. long ISI was the within-subject factor. The short ISI was 250 ms and the long ISI was 15 seconds for all participants. These values were chosen to ensure that at the short ISI any iconic store of the search array would still be present and at the long ISI any potential short-term store (e.g., iconic memory or working memory) would have had sufficient time to decay.

EXPERIMENTAL CONDITIONS

Each participant was tested in one of three experimental conditions. Each condition consisted of one block of practice trials and two blocks of experimental trials (one with a short ISI and the other with a longer ISI). The practice block consisted of 16 trials and used a neutral prime stimulus (XXXX) with an ISI of 1000ms. The experimental blocks each consisted of 160 test and 160 neutral trials intermixed within a block. Short and long ISI blocks were counterbalanced across participants within a given condition.

80% Valid Condition

In this condition prime-target pairs were the same in 80% of the test trials and different in the other 20%. Participants were informed at the beginning of each testing block that they should expect the target to be identical to the prime in 80% of the trials. For example, if the prime was stimulus item A the participant was told to expect the target to be stimulus A 80% of the time. Thus same pairs were expected in most cases.

50% Valid Condition

In this condition the prime was identical to the target in only 50% of the test trials. That is, maximum uncertainty existed about which of two targets would be presented (viz., the prime provides no predictive information). This condition allowed for the examination of the effects of relatedness independent to those of expectancy.

20% Valid Condition

In this condition prime-target pairs were related (viz., the same) in only 20% of the trials. Participants were informed at the beginning of each testing block that the target would be the same as the prime only in 20% of the trials. Since the prime was

valid on only 20% of the trials, the observer expected the target to be unrelated to the prime more often than not. Thus, if the prime was stimulus item A the participant was told to expect stimulus B 80% of the time.

PROCEDURE

Prior to conducting the experiment, all participants were asked to demonstrate informed consent by signing a standard consent form. After signing the consent form, the participant's visual acuity was tested to ensure normal levels (20/20) for both near and distance acuity after any necessary refractive eyewear. Distance acuity was tested using standard Bailey-Lovie acuity charts (Bailey & Lovie, 1976) and near visual acuity was measured using tumbling E charts.

After ensuring normal acuity levels, the participant was seated in front of the testing computer to begin the experiment. The researcher then provided a brief overview of the experiment and allowed ample time to answer any questions the participant had prior to beginning the experiment.

Preliminary Visual Discrimination Task

Prior to beginning the search task, the participant performed a discrimination task to determine the search display durations needed to obtain target identification accuracies of 75% (moderate level) and of 95% (high level). These two accuracy levels were chosen because pilot data suggested that above the high accuracy level participants may display "ceiling effects" and below the moderate accuracy level the data may be variable because they are so near threshold for a two alternative forced choice task.

The discrimination task consisted of 200 trials in which the duration of the search array was varied. There were 20 trials for each display duration (ranging

from 100ms to 1000ms in 100ms increments). The stimuli used in this task were the same as those used in the search task. All trials used the neutral prime.

In this discrimination task participants began each trial by pressing the spacebar on the keyboard. Immediately after pressing the spacebar, the prime appeared in the middle of the screen for only 100 milliseconds. Afterwards, a fixation point appeared that remained on the monitor for the duration of the trial. An ISI of 1000 ms was used in this task after which the search array was displayed. The participant's task was to identify which of two targets was present and where it was located within the array.

Table 1 lists the individual participant's search array display duration for both the moderate and the high accuracy levels as determined by the discrimination task.

Table 1 – Individual Search Array Durations

Participant	Moderate Accuracy Level (75% accuracy)	High Accuracy Level (95% accuracy)
1	200 ms	300 ms
2	250 ms	400 ms
3	250 ms	350 ms
4	300 ms	400 ms
5	350 ms	450 ms
6	250 ms	300 ms
7	200 ms	300 ms
8	300 ms	500 ms
9	250 ms	450 ms
10	350 ms	550 ms
11	250 ms	400 ms
12	250 ms	550 ms

Visual Search Task

After completing the discrimination task the participant began the search task. The experimental instructions for the search task stressed the point that accuracy was much more important than speed and instructed participants to take as much time as they needed in order to be as accurate as possible.

The first part of this search task consisted of one block of practice trials intended to familiarize the participant with the task, the controls used to initiate a trial and to respond, the different stimuli used, and the overall format of the experiment. This practice block contained sixteen neutral trials. The trials used a neutral prime, XXXX with an ISI of 1000ms. As in the discrimination task participants began each trial by pressing the spacebar on the keyboard after which the prime was flashed briefly and after the appropriate ISI had passed the search array was displayed, see Figure 7.

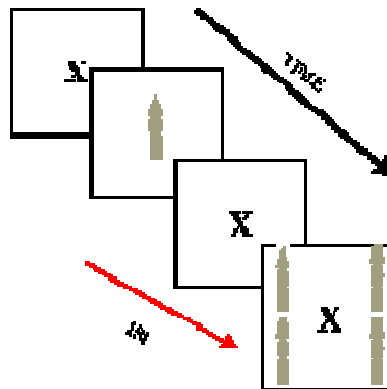


Figure 7 – Schematic of a valid trial

Participants were asked to identify which target (A or B) was presented. This target identification response was made by pressing a key labeled A or B on their keyboard. Both response time and accuracy were measured for target identification. As the experimental instructions stressed the importance of accuracy, RT data were collected

incidentally. The participant was then asked to indicate the target's location by pressing one of four keys on the numeric keypad that corresponded topologically to the spatial position of the stimuli. For example, 1 for the bottom left position and 3 for the lower right position. Only response accuracy was measured for target location.

After completing the practice block the participant engaged in four experimental blocks of trials. These blocks included one involving a short ISI and one a long ISI for each display duration determined from the discrimination task so that performance would approach either 75% or 95% accuracy levels. The procedures and tasks were the same in the experimental blocks as in the practice. The order of blocks (short vs. long ISI and 75 vs 95% accuracy level) was counterbalanced across participants within each condition. Before each block of trials the participant was shown the relevant prime (A for three groups and B for three groups) and told the proportion of the trials (20%, 50%, or 80%) for which the prime was a valid predictor of the target. Experimental conditions were also balanced across participants.

A debriefing session followed the end of the experiment. During this session the researcher explained the overall goals and research value of the experiment and answered any questions the participant may have had. Due to the need for naive participants this information was intentionally kept general. Participants were also informed that upon completion of all data collection they would be able to obtain a more thorough explanation of the study, should they wish.

CHAPTER 3

RESULTS

To put the results in context, here is an overview of the results and their significance. The results of this study support the stance that relatedness is fast acting and readily available to the system for processing, but decays quickly. Furthermore, the data also support the claim that expectancy takes time to build up before it becomes available to the system for processing, but persists for a longer duration than visual relatedness.

At short ISIs, the same prime-target pairs produce better accuracy than the different prime-target pairs in all conditions, suggesting that visual relatedness affects performance early whereas expectancy has no effect. Expectancy's role became apparent at the long ISI for both the 20% and 80% valid conditions. In the 80% valid condition the expected same-pairs produced higher accuracy than the unexpected different-pairs at the long ISI. In the 20% valid condition, the expected different-pairs produced higher accuracy than the unexpected same-pairs at the long ISI. These results are consistent with Neely's predictions, which assume only iconic store and expectancy influence performance. They also could be consistent with predictions that assume a long-lasting visual implicit memory also influences performance.

Results for the 50% valid condition, however, rule out an interpretation based on long-lasting visual information via implicit memory. In the 50% valid condition the prime provides no useful information about which of two targets will be present and, thus, expectancy plays no role in this condition. As Neely predicted, at the long ISI there

is no significant difference in accuracy for the same and different prime-target pairs. If visual information were still available at the long ISI, then accuracy should have been better for the same prime-target pairs than for the different prime-target pairs, contrary to the obtained results. The analyses and their implications are discussed in more detail below.

COMPARISON BETWEEN PRIMES

Mixed measures analyses of variance were conducted on each of the three experimental conditions to determine whether there were any differences in performance between the two different prime stimuli used. These analyses revealed that for all observed measures in each of the three conditions there were no significant differences between the two primes. As a result, in all subsequent analyses participants were grouped together within their respective conditions regardless of prime stimulus used.

ANALYSIS OF RESPONSE TIME DATA

As stated previously the experimental instructions stressed accuracy over speed of response. Participants were instructed to take as much time as necessary to be as accurate as possible; collecting RT data for analyses purposes was only incidental.

The RT data yielded no significant effects in any of the three experimental groups for either the moderate or high accuracy levels. As a result the analyses of these data have been omitted from this section and are included instead in the Appendix.

OVERVIEW OF GROUP ANALYSES

A repeated measures ANOVA was used for each of the three experimental groups. These were 3 X 2 ANOVA with three levels of prime-target relatedness (same, different, and neutral) and two levels of ISI (short and long). Planned comparisons were

also conducted on same vs. different conditions at either short or long ISIs to test the different predictions made by the two competing approaches. Although the omnibus ANOVAs included the neutral condition, the planned comparisons and the data shown in Figures 7, 8, and 9 only include the same-pair and different-pair conditions because these were the key elements in distinguishing between the approaches and the neutral condition only served to clutter the figures.

20% Valid Condition

In the 20% valid condition the prime predicted the occurrence of an identical target on only 20% of the trials, therefore unrelated prime-target pairs were *expected* on 80% of the trials. Neely's approach predicts better performance at the short ISI for the same pairs and better performance at the long ISI for the expected, different pairs. Schacter and Cooper's approach also predicts better performance for same pairs at the short ISI. The predictions based on Schacter and Cooper's approach for performance at the long ISI vary depending on the relative strengths of visual relatedness and expectancy.

The data from the current study support the hypotheses derived from Neely's approach. However, the data also would support the hypothesis derived from Schacter and Cooper's approach in which the strength of expectancy at long ISI is much greater than that of visual relatedness. That is, target identification and localization data show that same pairs produce better performance at the short ISI, but different pairs produce better performance at the long ISI. These trends were present at both the 75% and the 95% accuracy levels. Thus, the 20% valid condition cannot distinguish between

predictions based on Neely's approach and a specific version of Schacter and Cooper's approach.

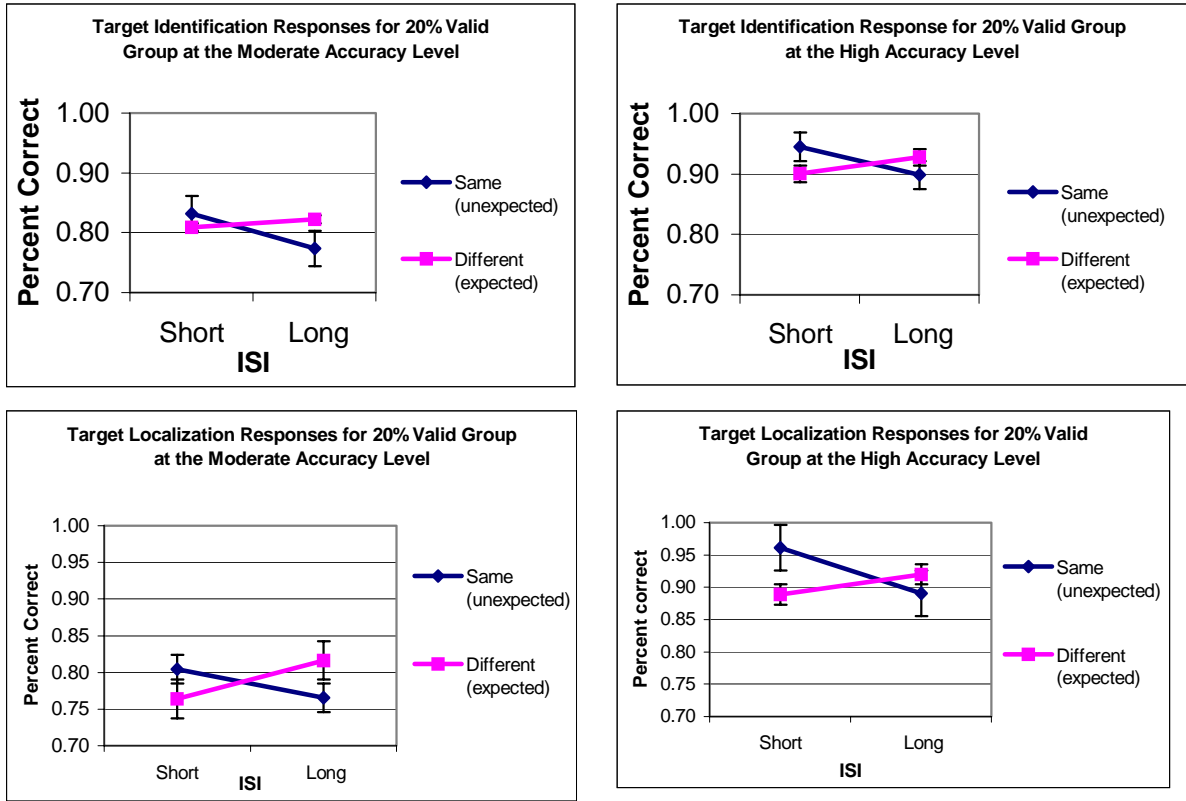


Figure 8 – Target Identification and Localization Data for 20% valid group. Error bars represent +/- 1 SEM.

Target identification

The analyses involving target identification data revealed main effects for type of pair, $F(2,3) = 12.398$, $p < .007$ at the moderate accuracy level and $F(2,3) = 7.633$, $p < .022$ at the high accuracy level. The analyses also revealed a main effect of ISI at both accuracy levels, $F(1,3) = 10.236$, $p < .049$ at the moderate accuracy level and $F(1,3) = 13.061$, $p < .036$ at the high accuracy level.

In addition to these main effects a significant pair type by ISI interaction was revealed at both accuracy levels, $F(2,3) = 28.420$, $p < .001$ at the moderate accuracy level

and $F(2,3) = 18.603$, $p < .003$ at the high accuracy level. This interaction indicates that same pairs produce better performance at the short ISI but that this effect of relatedness reverses at the longer ISI where expectancy is assumed to affect performance.

Planned comparisons were performed to determine whether or not the differences between pair types at each ISI were statistically significant. For both accuracy levels performance was significantly better for same pairs than different pairs at the short ISI, $t(3) = 7.251$, $p < .005$ at the moderate accuracy level and $t(3) = 4.138$, $p < .026$ at the high accuracy level. As predicted this effect did reverse at the long ISI where for both accuracy levels different (expected) pairs produced significantly better performance than same (unexpected) pairs, $t(3) = 10.151$, $p < .002$ at the moderate accuracy level and $t(3) = 5.174$, $p < .014$ at the high accuracy level.

Target localization

The analyses of the target localization data for the 20% group revealed similar trends as those for target identification. Main effects of pair type and ISI approached but failed to reach significance at the moderate accuracy level. However there were significant main effects for both pair type, $F(2,3) = 23.378$, $p < .001$, and ISI, $F(1,3) = 3203.560$, $p < .001$, at the high accuracy level.

As with the target identification data, a significant pair type by ISI interaction was found at both accuracy levels, $F(2,3) = 6.010$, $p < .037$ at the moderate accuracy level and $F(2,3) = 14.202$, $p < .005$ at the high accuracy level. Again as with the interaction revealed by the target identification data, this interaction indicates that same pairs produce better performance at the short ISI but that this effect of relatedness reverses at the longer ISI where expectancy is assumed to affect performance.

Planned comparisons showed that at the moderate accuracy level same pairs produced moderately significantly better performance than different pairs at the short ISI, $t(3) = 2.917$, $p < .06$, whereas different (expected) pairs produced significantly better performance than the same pairs at the long ISI, $t(3) = 3.324$, $p < .048$. At the high accuracy level same pairs produced significantly better performance than different pairs at the short ISI, $t(3) = 6.593$, $p < .007$. The difference between expected (different) and unexpected (same) pairs at the long ISI approached but failed to reach statistical significance.

50% Valid Condition

In this condition the prime provided no useful information about which target was to be presented on any given trial, thus maximum uncertainty existed and participants did not know which target to expect. Both approaches predict that same pairings produce higher performance than different pairs at the short ISI. However, at long ISIs Neely's approach predicts no difference in performance between same-pair and different-pair conditions, whereas Schacter and Cooper's approach predicts same-pair performance will continue to be significantly better than different-pair performance.

As Neely's approach predicted, both target identification and localization, relatedness produced better performance at the short ISI and expectancy had no effect in this condition.

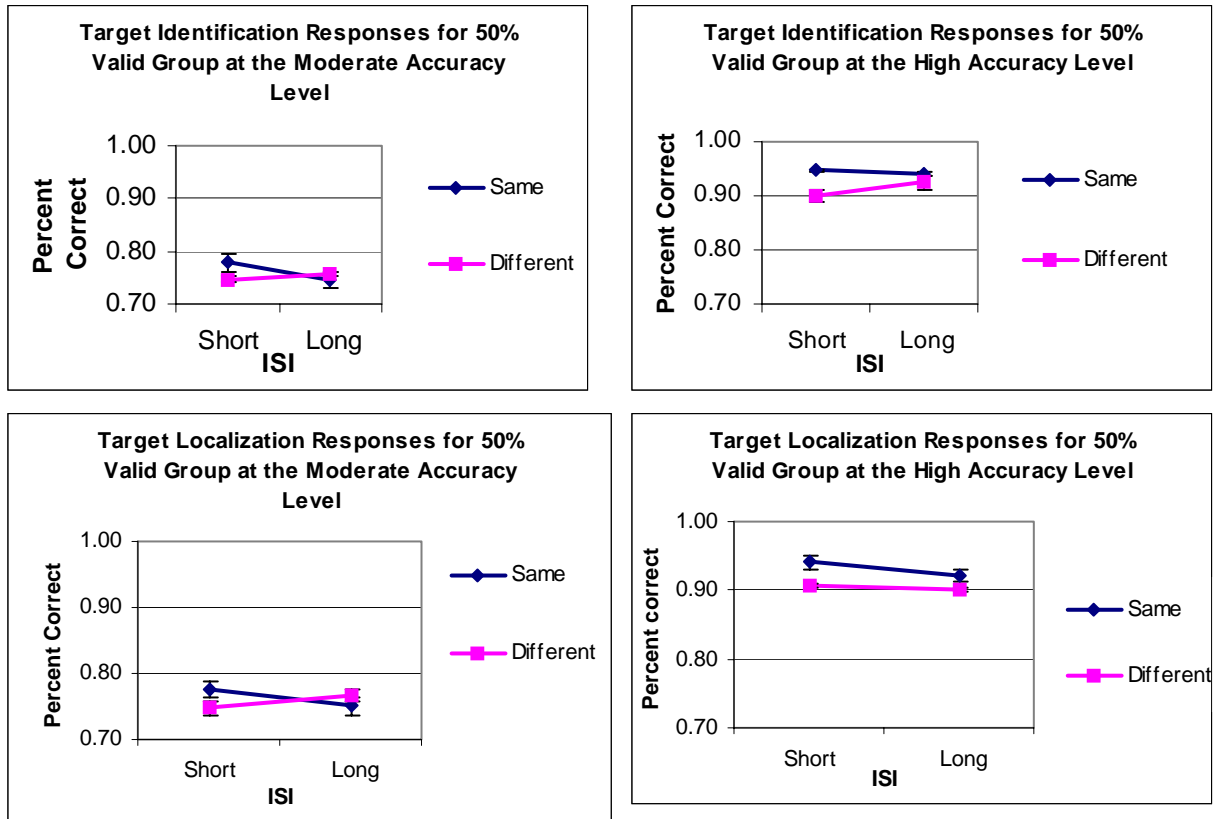


Figure 9 – Target Identification and Localization for 50% valid group.
Error bars represent +/- 1SEM.

Target identification

In this condition, the analysis of variance revealed significant main effect of prime-target pair at both accuracy levels, $F(2,3) = 11.690$, $p < .009$ at the moderate accuracy level and $F(2,3) = 7.747$, $p < .022$ at the high accuracy level. No significant main effect of ISI was present at either accuracy level. In addition to the main effects, a significant pair type by ISI interaction, $F(2,3) = 12.005$, $p < .008$, was present at the moderate accuracy level and a similar interaction that approached significance was present at the high accuracy level.

Planned comparisons showed that at the short ISI same pairs produced significantly better performance than different pairs at both accuracy levels, $t(3) = 4.891$, $p < .016$ at the moderate accuracy level and $t(3) = 3.896$, $p < .03$ at the high accuracy level. No significant differences between pair types existed at the long ISI for either accuracy levels.

Target localization

The analysis of variance revealed similar trends for target localization as those found for target identification. Again, there was a significant main effect of pair type at both accuracy levels, $F(2,3) = 8.249$, $p < .019$, at the moderate accuracy level and $F(2,3) = 12.946$, $p < .007$ at the high accuracy level. No significant main effect of ISI existed at either level. In addition, no significant pair type by ISI interaction was present at either accuracy level. There was a pair type by ISI interaction approaching significance at the moderate accuracy level but it failed to reach statistical significance.

Again planned comparisons showed that at both accuracy levels the same pairings produced significantly better performance at the short ISI than different pairs, $t(3) = 4.803$, $p < .017$ at the moderate accuracy level and $t(3) = 3.196$, $p < .049$ at the high accuracy level. No significant differences between pair types existed at the long ISI.

80% Valid Condition

In this condition both approaches predict that the same prime-target pairs would produce better performance at the short ISI due to visual relatedness. In addition it was predicted that at the long ISI these same pairs (which were expected on 80% of the trials) would again produce better performance.

Furthermore, Neely's approach predicts a flat slope (i.e., no difference in performance) whereas; Schacter and Cooper's approach allows for relatedness and expectancy to work synergistically and may predict even better performance for same pairs and worse performance for different pairs at the long ISI as compared to the short ISI. The results obtained in the current study indicate that in the 80% valid condition, related (expected) prime-target pairs produce a higher degree of performance than different pairs regardless of the duration of the ISI for both target identification and localization at both accuracy levels.

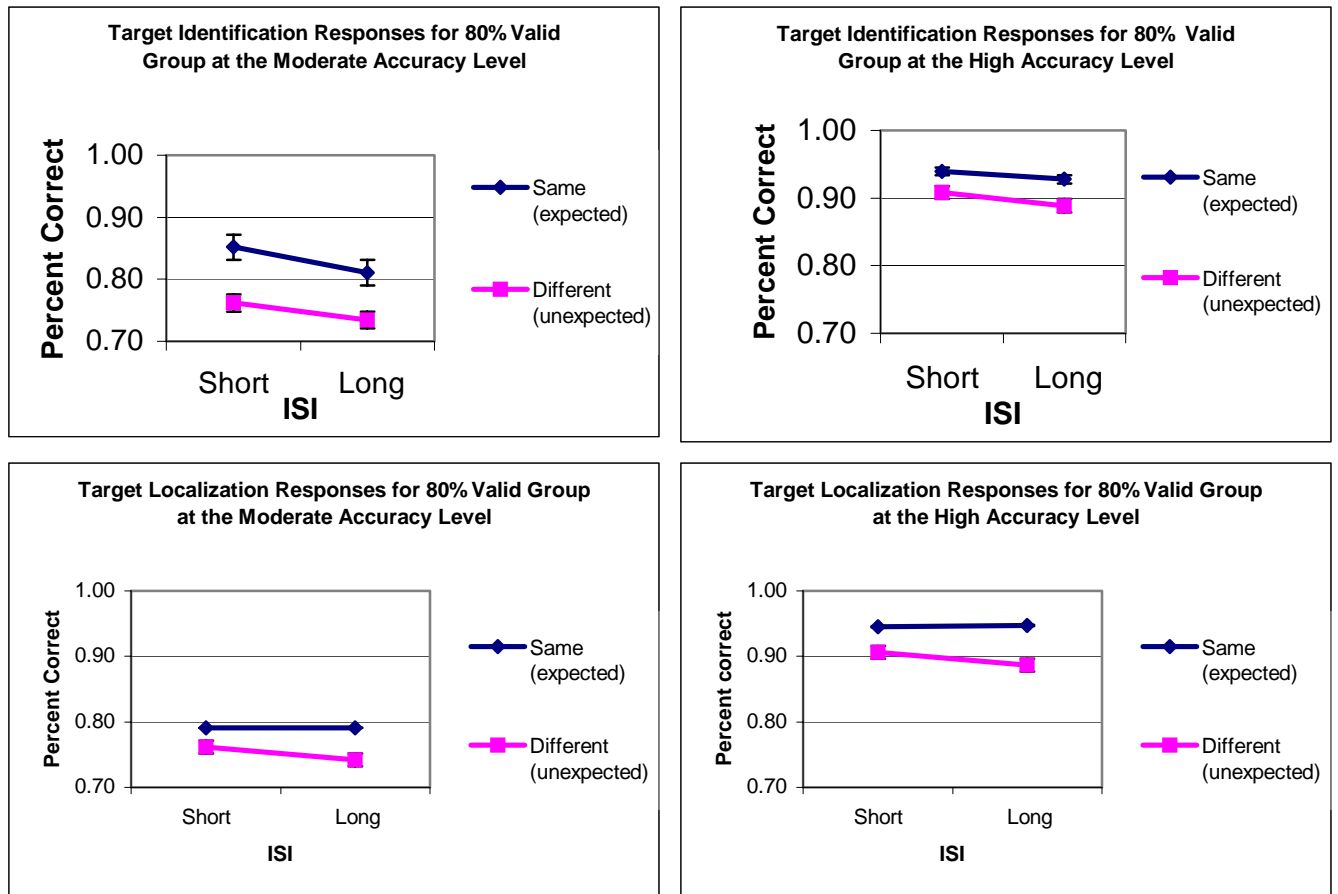


Figure 10 – Target Identification and Localization Results for 80% valid group
Error bars represent ± 1 SEM.

Target identification

The analyses of variance revealed a significant main effect of pair type at both accuracy levels [$F(2,3) = 6.707$, $p < .03$ at the moderate accuracy level and $F(2,3) = 8.859$, $p < .016$ at the high accuracy level] but no main effect of ISI and no interactions were revealed.

Planned comparisons revealed that at the short ISI same pair types produced significantly better performance than different pairs for both accuracy levels, $t(3) = 3.858$, $p < .031$ at the moderate accuracy level and $t(3) = 5.856$, $p < .01$ at the high accuracy level. Furthermore the same pairs also produced significantly better performance than different pairs at the long ISI at the 75% level, $t(3) = 3.173$, $p < .05$ at the 75% level and moderately significantly better performance at the 95% level, $t(3) = 2.677$, $p < .075$. No interaction was present at either accuracy level.

Target localization

The analyses of variance revealed similar results for target localization as those of the target identification. At both accuracy levels a significant main effect of prime target pair was present ($F(2,3)=4.550$, $p=.063$ at the moderate accuracy level and $F(2,3)=26.574$, $p=.001$ at the high accuracy level) but no effect of ISI and no significant interactions.

Planned comparisons revealed that at the short ISI same pairs produced significantly better performance at the moderate accuracy level, $t(3) = 3.155$, $p < .05$ and moderately significantly better performance at the high accuracy level, $t(3) = 2.950$, $p < .06$. At the long ISI these planned comparisons revealed that same pairs produced

marginally significantly better results at the moderate accuracy level, $t(3) = 2.734$, $p < .07$
and significantly better performance at the high accuracy level, $t(3) = 9.187$, $p < .003$.

CHAPTER 4

CONCLUSIONS AND IMPLICATIONS

The obtained results suggest that visual relatedness is a bottom-up process, probably mediated by a short-term iconic store, that affects search performance early, but whose effects quickly fade away. They also suggest that expectancy is a top-down process that requires time to build up before it can affect visual search performance, but whose effects are more long lasting than visual relatedness. There is no solid evidence here that visual implicit memory, based on relatedness between a prime and target, affected performance. Thus, results are consistent with Neely's two-process approach (Neely, 1977).

These results are especially intriguing, given how the present experiment differs in several different ways from Neely's (1977) experiments using semantic priming. First, the current study employed visual stimuli composed of geometric shapes rather than lexical stimuli using words. Second, both target and distractor stimuli in the current study were exemplars of the same perceptual structural category – they had the same structural arrangement of three geometric components which subtly differed from each other (e.g., an ellipse rather than a rectangle), Neely used words that came from very different semantic categories rather than exemplars from the same category. Third, the present study used a visual search paradigm rather than a classification paradigm. Finally, accuracy was emphasized as the dependent measure in the present study rather than response time. In the present experiment all stimuli were briefly presented for the same fixed duration, although the duration between the offset of the prime and the onset of the visual search array was varied.

These differences aside, it is apparent that Neely's approach sufficiently predicts the results obtained here. Thus, it seems that the underlying processes which account for observed benefits from cognitive psychology's research with semantic priming (e.g., Posner & Snyder, 1975; Neely, 1977) are also at work in the perceptual-cognitive processes that involve visual priming in a visual search task.

Although the present experiment showed no evidence for a long-lasting visual implicit memory, this may have been an unfair test of Schacter and Cooper's concept. Their research focused on the visual structure of three-dimensional objects. The stimuli used in the present study did not differ on overall structure but rather on subtle differences in the components that made up the structure (e.g., an ellipse vs. a rectangle), all stimuli were exemplars from the same visual structural category rather than from different structural categories. Rosch (1975) reported that category priming produces facilitating effects for both good and bad exemplars of a given category. Thus, implicit memory of the prime may have affected all stimuli, both targets and distractors. If each stimulus comes from a different structural category (see Newell et al., 2004), this may be a better test of whether visual structural implicit memory can influence search performance. Future research is planned to investigate this possibility.

The results of this study have implications that extend beyond a basic perceptual-cognitive domain. For example, these results have potential applied implications in the domain of systems and interface design. It is a well-documented phenomenon that even users who would be classified as experts (i.e., highly familiar with and proficient in a given task) still commit performance errors. This is especially true when the user is experiencing factors such as increased working memory load and fatigue (Gray, 2000).

One aspect of “good” design stressed by engineering psychologists and other human factors professionals is the need for designers to reduce the amount of information users must maintain in memory (i.e., reduce working memory load). One way of accomplishing this is by providing cues built into a system that the user can take advantage of thereby reducing the load placed on his/her working memory.

This study identified two distinct processes that can be taken advantage of in precisely this manner. For example, in mission critical tasks where split-second decisions determine the success or failure of the mission we can encourage designers not to rely on the user’s experience and/or expectations. The data from this study clearly indicates that expectations require time to build before becoming available to the system for processing whereas relatedness is available immediately. Thus designers should be encouraged to prime relatedness in these tasks requiring split-second decisions to both decrease working memory load and to maximize performance.

Further investigation of these two processes (and other potential processes) and a more complete mapping of their time courses will allow designers to make better use of primes and other cues in their designs in order to reduce load on working memory. Furthermore, investigating and determining factors that influence visual search performance and reduce working memory load can greatly increase the ease of and as a result, the productivity of tasks involving visual interfaces.

After careful consideration of the data analysis and what it revealed, it was determined that a potential methodological flaw may have existed in this study. There was only one prime per participant for all experimental trials. This potential confound

may have reduced the effect sizes of the interactions present in both the 20% and 50% valid primes conditions.

On trials in which a participant had no sensory information from the search array because of blinking or looking away from the display, the participant could have simply chosen the expected target. This response was guaranteed to be correct 80% of the time (a fact the participant knew ahead of time). The data suggest that this strategy was not employed exclusively by participants as evidenced by the observed effect of visual relatedness at the short ISI in the 20% valid condition where the related target was unexpected and the 50% valid condition where the prime offered no predictive power regarding the subsequent target. The data do not, however, rule out the use of this strategy in trials where uncertainty due to lack of sensory information occurred and to what extent this occurred. Future research is planned to address this potential confound by using blocks of trials that mix the prime stimuli (i.e., use both target A and B as primes within a block) so that each prime is used on 50% of the primed trials.

Finally, although the data do favor the position that visual relatedness is associated with iconic memory and not with a longer-lasting implicit memory, this claim cannot be definitively made based on the current study. Having tested only two ISIs that differed by such a large amount of time (more than 14 seconds) it is difficult to determine when the effect of relatedness dissipates. Perhaps this effect lasts much longer than the duration of iconic memory as defined by Coltheart, but clearly the effect dissipates in less than 15 seconds as evidenced by the results in the 50% valid condition where no expectancy existed and *no difference* between pair types was revealed.

Future research is planned to map out more thoroughly the time-course involved by incorporating more intermediate ISIs. This will make it easier to better distinguish the effects of priming visual relatedness versus expectancy.

APPENDIX

MEDIAN REACTION TIME DATA FOR TARGET IDENTIFICATION RESPONSES

As stated previously the experimental instructions stressed accuracy over speed of response and participants were told to take as much time as necessary to be as accurate as possible. As a result the collection of response time was incidental to the collection of response accuracy.

The RT data yielded no significant effects in any of the three experimental groups for either the moderate or high accuracy levels. The following figure illustrates these results. Interquartile error bars are used in all of the following graphs.

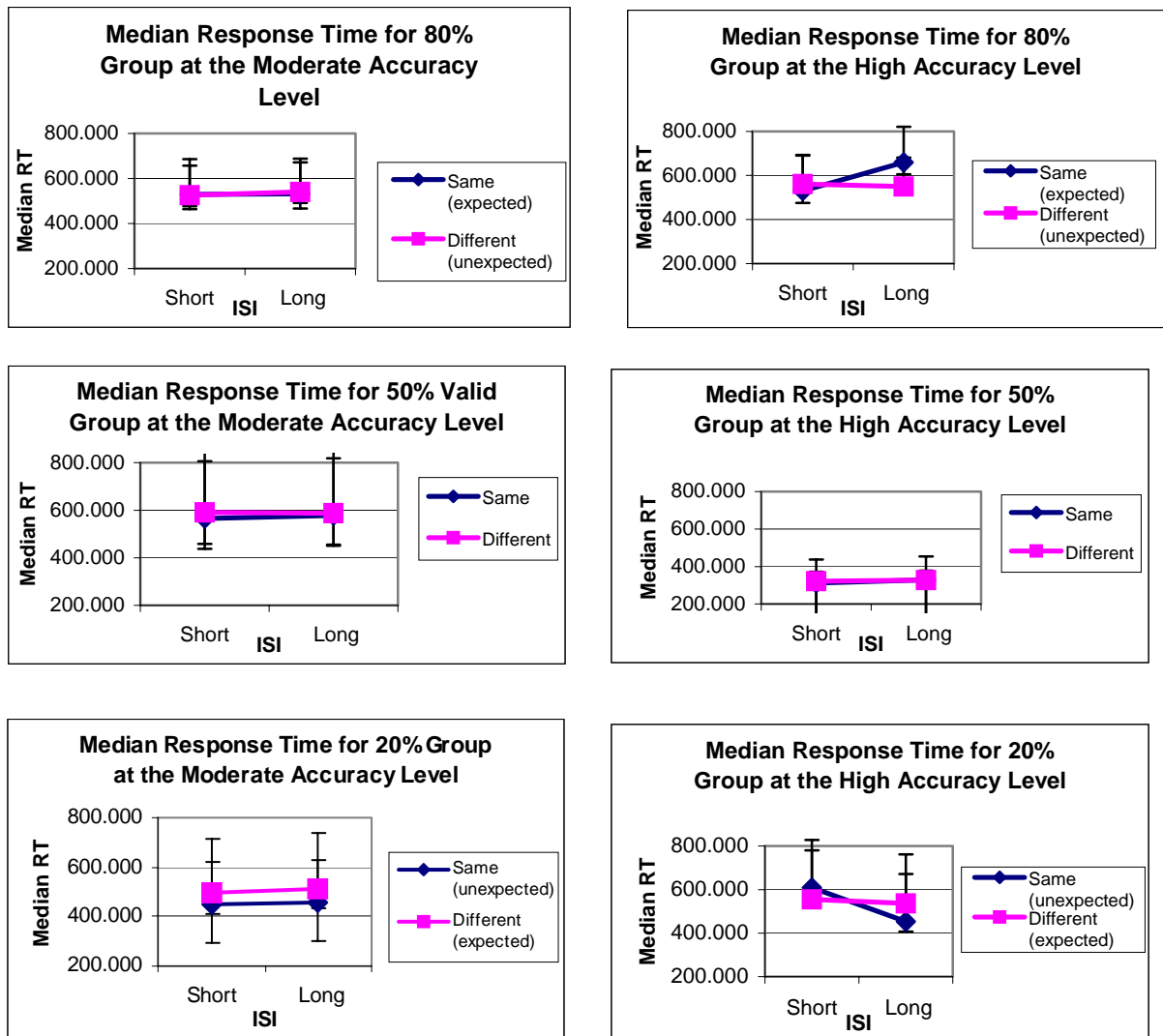


Figure 11 – Response Time Data. Error bars represent interquartile range

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